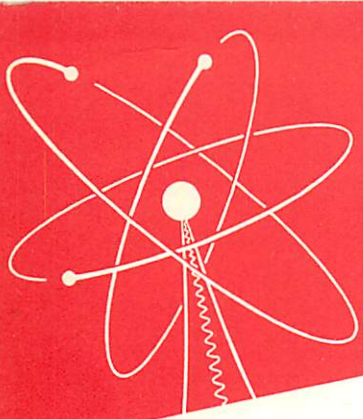

SYNC CLIPPERS

Lesson T2C-10A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-10A

SYNC CIRCUITS AND D-C RESTORERS

4141 Belmont Ave.
Chicago 41, Illinois

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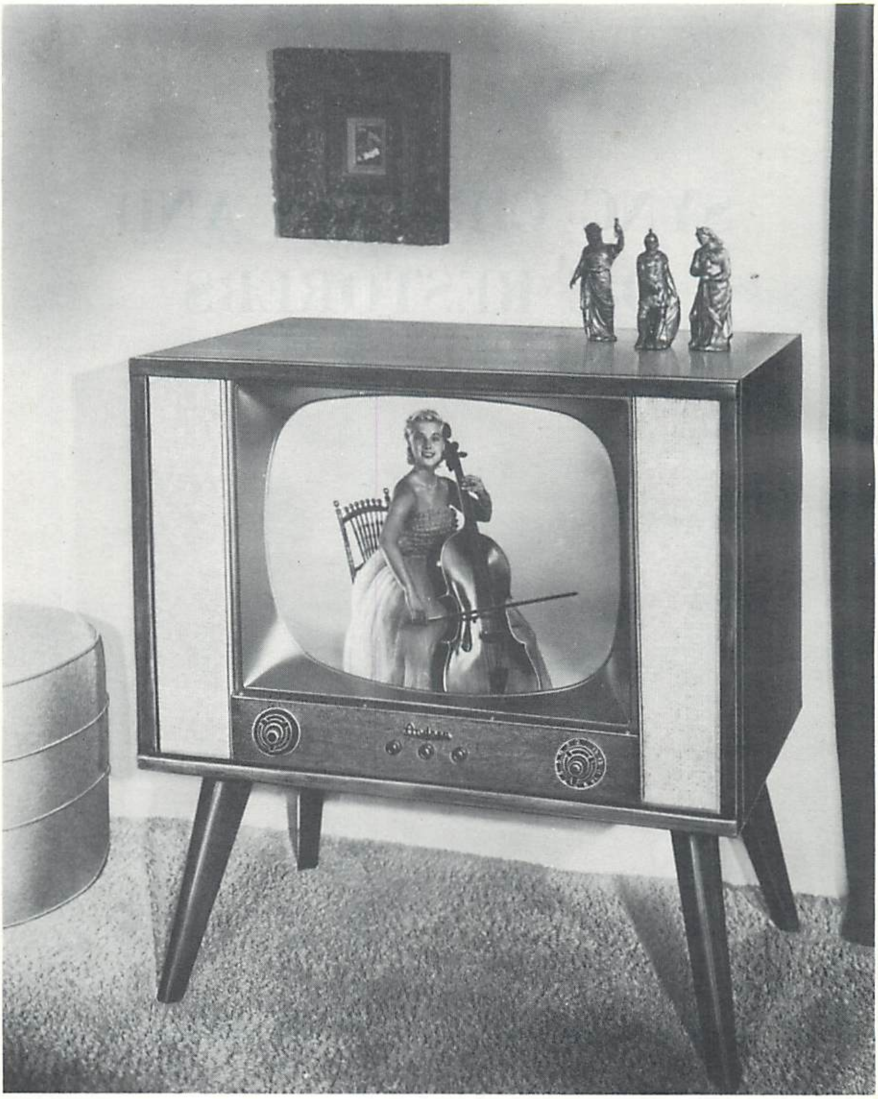

Simplicity is the keynote in the cabinet design of this console television receiver.
Courtesy Andrea Radio Corp.

SYNC CIRCUITS AND D-C RESTORERS

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Lots of folks have a good aim in life . . . but most of them don't know when to pull the trigger.

—Gilerafter

SYNC CIRCUITS AND D-C RESTORERS

To troubleshoot efficiently the many makes and models of television receivers on the market today, the television serviceman needs a good understanding of the requirements of the various sections of the receiver as well as of the operation of the basic types of electron circuits. With this knowledge, he employs troubleshooting techniques to determine whether a given section performs all of the functions assigned to it.

The preceding lesson described the various functions of the group of circuits known as the sync section, and explained in detail the operation of the electron tube and filter circuits which fulfill the sync requirements of the television receiver. Also, we mentioned that the basic circuits are employed in different combinations by the various designers to accomplish the desired results. Thus, in analyzing a circuit arrangement which he has not encountered previously, the technician applies his knowledge of circuit theory to determine which functions are performed by each stage and circuit component in the section.

This lesson describes the sync circuits employed in a number of commercial receiver models to illustrate the variations in design, all of which satisfy the various sync section requirements explained previously. The knowledge gained in the study of these circuits should enable you to make similar analyses of the sync sections employed in other makes and models.

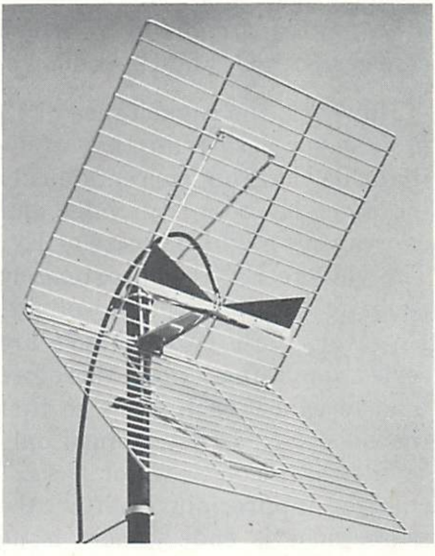
As explained, the sync section separates the sync signals from the remainder of the video wave. Also, it amplifies and inverts the sync pulses when required, and filters the composite sync signal so that only pulses of the proper frequency are applied to each deflection circuit. In addition, the sync circuit includes some more or less elaborate means of preventing noise energy from passing through the section to cause loss of sync by the horizontal and vertical deflection oscillators. Operating as limiters, both the sync separator and the sync amplifier remove some noise energy by their action in clipping off portions of the signal applied to their input. Besides this, resistor and capacitor networks are used to block noise in some sync circuits, while others employ one or more electron tube stages for this purpose. In fact, many sync circuit designs are much alike except for the method employed to cancel or filter noise pulses.

COMPLETE SYNC CIRCUITS

Emerson

Figure 1 shows the sync circuit employed in a number of Emerson Television receiver models. In this circuit, the sync separator tube is the triode section of a type 5U8 triode-pentode, while the sync phase inverter employs one section of a duo-triode type 6SN7GTB. Tube V_1 is the video amplifier, the plate circuit of which contains peaking coils L_1 and L_2 and load resistor R_2. Capacitor C_1 couples the amplifier output to the cathode of the picture tube as indicated. From the junction between L_2 and R_2, the negative picture phase video signal is coupled through R_3, R_4, C_2, and the parallel components R_6 and C_3 to the grid of the sync separator tube V_2. The plate of this triode is operated at 100 volts, and the cathode is grounded. The peaks of the positive going sync pulses of the input signal produce grid current which charges C_2 and C_3 to the polarity indicated.

Between sync pulses, C_2 discharges slightly through R_5 to produce the grid leak bias voltage E_{R_5}. In series aiding between grid and cathode, voltages E_{C_3} and E_{R_5} bias the tube negative beyond cutoff, so that plate current is produced only by the positive sync pulses. These sync pulses produce pulses of plate current which reduce the plate voltage, resulting in the negative voltage pulses indicated at the plate of V_2. In this receiver, positive sync pulses are required to properly control the deflection oscillators. Therefore, tube V_3 is employed to invert the phase of the pulses as shown. Under the action of grid leak bias, and with its plate operated at 65 volts, V_3 also serves as a clipper or limiter. From the junction between R_{10} and R_{11}, the positive sync pulses are applied to the differentiating circuit C_5R_{12}, and in turn the horizontal deflection circuit, and to the two-section integrating circuit $R_{13}C_6$, $R_{14}C_7$ and the vertical deflection circuit.



A television receiving antenna designed for reception in the uhf band.

Courtesy American Phenolic Corp.

Together with C_2 and R_5, resistor R_6 and capacitor C_3 form what is known as a double time constant network in the grid circuit of the sync separator. The purpose of this arrangement is to prevent large amplitude noise pulses, or "spikes", from changing the bias on the separator. Increas-

#1

#.1

ed bias for even the short time of the noise pulse can cause a partial or total loss of vertical synchronism. Capacitor C_3 has a value of only 220 micromicrofarads compared with the .01 microfarad of C_2. Like the sync pulses, the noise spikes have positive polarity in the video amplifier output, but may have even greater amplitude. When such a noise spike or pulse occurs, it produces a large grid current in V_2 which charges both C_2 and C_3 as shown.

However, the capacitance of C_3 is so much less than that of C_2 that this charging current quickly increases E_{C_3} to a high value, but causes very slight increase of E_{C_2}. The voltage E_{C_3} is approximately equal to the noise pulse voltage. However, these two voltages are series opposing, and therefore tend to cancel each other so that the bias, E_{R_5}, is determined only by the charge on C_2 which has not changed appreciably. After the noise pulse is ended, there is no longer any need for the higher voltage of E_{C_3}, and capacitor C_3 discharges through R_6. An additional means for preventing large amplitude noise pulses from increasing the bias on V_2 is the "picture stabilizer" resistor R_4. In areas where there is considerable noise, or where signals are weak, this control is adjusted to insert resistance in the circuit, and thus increase the charging time constants in the coupling circuit.

It was mentioned that the sync phase inverter V_3 operates with grid leak bias. This condition exists even though the output of V_2 consists of negative going sync pulses. In the V_2 plate circuit, R_7 and R_8 form a voltage divider between B+ (125 v) and ground. The junction of these resistors supplies + 100 volts to the plate of V_2. Thus, during the intervals between pulses, the ungrounded end of R_8 is 100 volts positive. When sync pulses swing the V_2 plate in the negative direction, coupling capacitor C_4 discharges slightly through R_9 to provide negative pulses at the grid of V_3. The resulting reductions of V_3 plate current produce the positive plate voltage pulses as indicated.

In the plate circuit of the sync separator V_2, as each negative sync pulse is completed, the plate voltage returns to its operating value of +100 volts. However, as the wave-form drawn at this point in the Figure shows, a slight oscillation occurs during the first part of which the plate voltage rises a few volts above 100. This overshoot, as it is called, applies a momentary positive voltage to the grid of V_3, producing cathode to grid electron flow which charges C_4 to a little over 101 volts, and with the polarity indicated. During the remainder of the cycle, the series opposing voltages, E_{C_4} and E_{R_8}, apply a net bias of 100−101, or −1 volt to the grid of V_3. To obtain a steep rising front on the V_3 output pulses, it is necessary for C_4 to discharge very rapidly when the negative sync pulses are applied to it. #1 This rapid discharge action is obtained by connecting R_9 to B+ instead of ground.

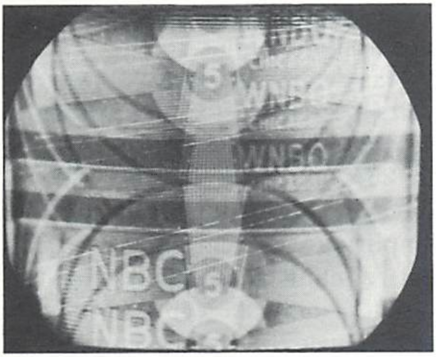
Bendix

Figure 2 shows the sync circuit employed in the Bendix television receivers which use chassis No. T19. In this circuit, the triode section of a type 5BE8 triode-pentode is employed as the sync separator. The triode section of a type 6AW8 triode-pentode serves as the sync clipper. From the junction between R_2 and R_3 in the video amplifier plate circuit, the negative picture phase video signal is coupled through R_4, C_2, and the parallel circuit R_5 and C_3 to the grid of the sync separator. Resistor R_4 serves as an isolating #2 resistor to prevent shunting the plate circuit of the video amplifier with the input capacitance of the sync separator tube.

Together with coupling capacitor C_2 and grid resistor R_6, the parallel circuit R_5C_3 form a double time constant network to prevent changes in grid bias due to noise pulses. Grid current charges C_2, and electrons leak off C_2 through R_5 and R_6. The resulting voltage across the 2.2 megohm resistor R_6 biases the tube beyond cutoff so that only sync pulses cause conduction. R_5 has a resistance of only 150,000 ohms to permit C_3 to discharge relatively quickly after a noise pulse has charged it as explained for the comparable circuit of Figure 1.

In the circuit of Figure 2, the video signal input to the grid of V_2 may vary between 25 and 135 volts peak to peak, but the sync separator limits the output pulses to 25 volts peak to peak. Thus, the sync pulses in the output have amplitude as great as that of the entire input video signal when the input is only 25 volts PP. However, since the plate current is varied from cutoff to saturation with even this low input level, an increase of input signal amplitude cannot increase the output level. That is, the amplification obtained decreases as the input signal increases, to provide the constant output amplitude indicated.

As shown in the Figure, the plate of V_2 is direct-coupled to the grid of the sync clipper V_3. Both the V_2 plate and V_3 grid operate at 21 volts positive with respect to ground. The voltage across cathode resistor R_8 places the V_3 cathode at +21.5 volts with respect to ground. Therefore, the sync clipper tube operates with its grid at 0.5 volt negative with respect to its cathode, and with a plate voltage of 145 volts with respect to ground. The 25 volt PP amplitude of the input pulses is sufficient to drive V_3 into cutoff during the negative peaks. This action clips the peaks to provide output pulses with more constant flat tops.



Vertical rolling of the image is caused when noise pulses trigger the vertical deflection oscillator. This loss of synchronism may be due also to a sync circuit defect which prevents proper application of the sync signal to the vertical oscillator

From the plate of V_3, 70 volt PP positive pulses are applied to the three-section integrating circuit, R_9C_4, $R_{10}C_5$, $R_{11}C_6$, the output of which is coupled to the vertical deflection circuit. This receiver employs a horizontal frequency control circuit which requires both positive and negative sync pulses. To provide these outputs, the sync clipper is operated as a phase splitter. Thus, resistor R_8 is the cathode circuit section of the plate load, while R_{12} and R_{13} form a voltage divider in the plate circuit section. Positive sync pulses, 25 volts PP, are coupled through C_7 to the horizontal frequency control circuit, while the V_3 cathode supplies 25 volt PP negative pulses to this circuit by means of capacitor C_8.

RCA

A number of RCA television receiver models, such as the Model No. 24-D-655, contain the sync circuit shown in Figure 3. Here, both the video detector and first video amplifier are included to show the connections to the noise cancel circuit which employs the triode tube V_3. V_2 and V_3 are the pentode and triode sections respectively of a type 6AW8 triode-pentode. The V_4 and V_5 stages constitute the actual sync circuit. The sync pulses are separated in the sync amplifier which operates in the same manner as the sync separators of Figures 1 and 2.

The use of the term "SYNC AMPLIFIER" in the RCA schematic illustrates the differences in terminology employed by the various manufacturers. However, as you gain experience in circuit study, you will learn to recognize any given stage according to the functions performed by it, regardless of the name given to it. Clues to the functions are the location of the stage with regard to other stages, the arrangement and values of its circuit components, the type of tube used, and the operating voltages applied to the electrodes of the tube.

For example, in Figure 3, the video signal output of video amplifier V_2 is coupled through isolating resistor R_7, blocking capacitor C_4, and the parallel networks $R_{11}C_5$ and $R_{12}C_6$ to the grid of triode V_4. Thus, the V_4 stage is the first stage of the sync section, usually the stage in which the sync pulses are separated from the blanking and picture information. The 1.2 megohm grid resistor R_{13} and the grounded cathode indicate that the tube employs grid leak bias. Also, the indicated low plate voltage of 33.5 volts is typical of sync separator operation.

The sync output tube V_5 also employs low plate voltage, but its grid is operated at only −0.1 volt with respect to cathode. Also, the video detector is connected to supply a positive picture phase signal. Inverted by the V_2 stage, this signal has positive going sync pulses when applied to the grid of V_4, which is proper for sync separator operation. However, inverted by V_4, the sync pulses are negative going at the grid of V_5. Therefore, although V_5 can operate as a limiter and clip a portion of the signal applied to it, plate current is decreased in this tube by the input sync pulses. Thus, V_4 operates in the manner of a sync separator stage, while V_5 operates like the sync clippers and phase inverter amplifiers explained previously.

The noise cancel tube V_3 operates in the following manner. With no noise in the signal, V_3 is cut off by the negative voltage applied from the slider on R_5 through resistor R_4 to the grid. Peaking coils L_2 and L_3 and resistors R_2 and R_3 form the plate load of the video detector. The video signal appears with negative going sync pulses and negative going noise pulses across these components, due to the direction of the detector diode current. This current makes the cathode of V_3 negative with respect to ground.

With no noise in the signal, the negative voltage on the V_3 cathode is not sufficient to overcome the bias on the grid, and the tube remains cut off. However, a high amplitude noise impulse drives the cathode of V_3 highly negative, reducing the grid-cathode bias, and the tube conducts plate current. The negative noise pulse on the cathode of V_3 is equivalent to a positive pulse on the grid. Therefore, an amplified pulse of negative polarity is produced at the plate. At the same time, the negative going noise pulse is applied to the grid of V_2 to produce a positive noise pulse at the plate of this tube. Thus, the negative pulse at the plate of V_3 is coupled through C_2 to cancel the positive pulse coming from the plate of V_2, thus little or no noise is carried by C_4 to the input of V_4.

Further noise rejection is provided by the double time constant network in the sync amplifier grid circuit. Here, R_{11} and C_5 in parallel are connected between coupling capacitor C_4 and grid resistor R_{13}, as in the comparable circuit of Figure 2, while R_{12} and C_6 are located between the grid resistor and grid as in Figure 1.

Operating with its grid only slightly negative, tube V_5 of Figure 3 conducts grid current during the first part of the positive portions of the input signal. This current charges C_7 to provide a grid leak bias of -0.1 volt, as indicated. If it were not for a large resistance R_{15} between the grid and B+ this bias would build up to a larger voltage. However, due to the voltage divider action of resistors R_{15} and R_{16} in series from B+ to ground this voltage is held very close to zero voltage when V_5 is not conducting. However, the instant V_5 conducts the resistance of V_5 and R_{16} in parallel is so small compared to R_{15} that the voltage quickly goes negative with the sync pulse. Therefore the V_5 plate voltage has a steep rising front. This wave-form is desirable for accurate timing of the deflection generators. The output stage provides positive pulses to the vertical and horizontal deflection circuits from separate points in its plate circuit as indicated.

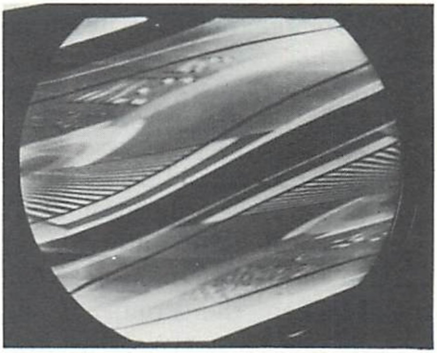
Du Mont

As mentioned previously, an undesirable action in the grid leak bias type of sync separator or clipper is the increase of bias produced by large amplitude noise pulses. This action is a direct result of the operating principle upon which this type of circuit is based. That is, the magnitude of the grid leak bias is determined by the peak amplitude of the signal. When the noise pulses exceed the amplitude of the sync pulses, which is often the case, the bias of the tube is increased. With increased bias, the separator tube operates farther below cutoff than normal, and the sync pulses are unable to overcome the bias sufficiently to produce appreciable conduction, if any. Thus, the sync circuit output consists of noise pulses, and small or no sync pulses, unless some method such as those described is employed to suppress or cancel the noise energy when it appears in the signal.

A sync clipper or separator in which the bias is determined by the time duration of the sync pulses, instead of the peak amplitude of the signal, is employed in the Du Mont RA-166, 167 and RA-170, 171 chassis. The circuit of the sync section used in these chassis is given in Figure 4. Here, the noise inverter V_1 provides negative going noise pulses to cancel the positive going noise pulses in the video signal applied to the grids of V_2 and V_3. The horizontal sync pulses are separated from the composite video signal by the 1st sync clipper, and the vertical sync pulses are separated from the composite video signal by the 2nd sync clipper. The sync pulse outputs of V_2 and V_3 are combined and applied to the cathode of the 3rd sync clipper V_4. This stage clips the tips of the sync pulses, and couples positive going pulses to the phase splitter V_5, which supplies both positive and negative pulses as required to the deflection circuits.

In the circuit of Figure 4, the video signal output of the video amplifier is impressed with negative picture phase, or positive sync phase, across the voltage divider consisting of resistors R_1, R_2, and R_3. From the tap between R_1 and R_2, this signal is applied through isolating resistor R_6 to the grid of V_2. The positive portions of the signal produce plate current in this tube. The resulting voltage across R_8 is applied through R_7 to C_1, and charges this capacitor so that its ungrounded plate is positive. Between V_2 plate current pulses, C_1 discharges through R_8 and R_7 to provide a voltage across these resistors which biases the cathodes of V_1, V_2 and V_3 positive with respect to ground.

Although a small positive voltage is applied from the video amplifier plate circuit through R_1 and R_6 to the grid of V_2, the positive bias on the cathode is sufficiently greater than the positive grid voltage to bias the tube negatively beyond cutoff. Therefore, V_2 conducts only during the sync pulses. Each time a sync pulse causes the 1st sync clipper to conduct, the voltage E_{R_8} is applied to C_4 and R_{11} in series, causing C_4 to charge through R_{11}. Electrons flow from ground through R_{11} to the lower plate of C_4, and from the upper plate through V_2 and the B (+300 v.) supply to ground. This current



A sync circuit defect which causes loss or partial loss of the sync pulses needed by the horizontal control circuit results in loss of horizontal synchronism with this effect on the image.

charges C_4 so that its upper plate is positive.

The horizontal sync pulses are 5 microseconds long and the interval between them is 58 microseconds. Likewise, there is a long interval of 32 microseconds between the equalizing pulses, each of which is only 2.5 microseconds in duration. Therefore, for the horizontal sync pulses and the equalizing pulses, C_4 charges slightly for each pulse, and has plenty of time to discharge before the next pulse arrives. R_{11} and R_8 form the discharge path for this capacitor. Since R_{11} carries both the charge and discharge currents for C_4, a voltage pulse is produced across this resistor each time a horizontal sync or equalizing pulse is applied to the grid of V_2.

On the other hand, the vertical sync pulses have a duration of 27 microseconds with intervals of only 4 microseconds between them. When the group of six vertical pulses arrives, the first charges C_4 to a relatively high voltage, and the capacitor discharges only a small amount in the 4 microsecond interval before the next pulse begins. Each vertical pulse adds more charge to the capacitor, which still retains most of the charge placed upon it by the preceding pulses. Thus, an accumulation of charge is built up on C_4. As the upper plate of C_4 is positive, this high voltage developed across the capacitor makes the cathode of V_2 very positive with respect to ground. Since making the cathode positive is equivalent to making the grid negative, this action increases the grid-cathode bias to reduce plate current in the tube. Due to this increase of bias, the plate current of V_2 is very small for all of the vertical sync pulses after the first.

This large voltage on C_4, produced by the long duration vertical sync pulses, is applied through R_7 and charges C_1 to provide the bias for V_1, V_2, and V_3. The short duration horizontal sync and equalizing pulses have almost no effect on this bias since, as explained, C_4 receives only a very small charge from each such short pulse, and those charges do not accumulate because C_4 discharges completely after each pulse. The advantage of this arrangement is that noise pulses, which have short duration also, cannot affect the bias on the sync clipper tubes. The bias is determined only by the 27 microsecond vertical sync pulses.

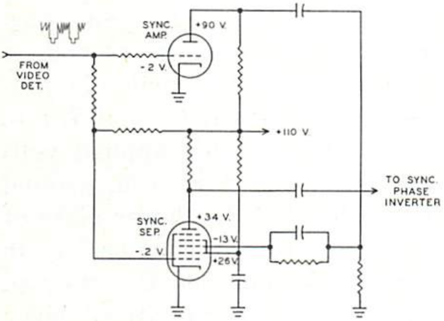
Since the V_2 plate current is small for all of the vertical sync pulses after the first, the voltage pulses produced across R_{11} by this tube are much too low in amplitude to be used for synchronizing the vertical deflection circuit. Therefore, the 2nd sync clipper V_3 is employed to provide the needed vertical sync pulses. Voltage from the cathode of V_2 is applied through resistor R_{10} to the cathode of V_3 to bias this tube negative beyond cutoff. The filter $R_{10}C_5$ prevents the horizontal sync and equalizing pulses from being applied to the V_3 cathode. However, these pulses charge C_5 so that the cathode of V_3 is slightly more positive than the cathode of V_2.

Directly connected by resistor R_9, the grids of tubes V_2 and V_3 would have the same voltage if it were not for the fact that the V_3 grid is connected through R_5 to the highest voltage point on the $R_1R_2R_3$ divider. That is, the B+ voltage in the video amplifier plate circuit is applied to this divider so that the upper end of R_1 is the most positive point. In turn, the voltage across R_1 is applied to a voltage divider consisting of R_5, R_9 and R_6. Connected to the junction between R_5 and R_9, the grid of V_3 is slightly more positive than the V_2 grid which connects to the junction between R_9 and R_6. With this arrangement, the grid-cathode biases on V_2 and V_3 are made about equal. Neither grid is very positive since R_5 is 15 megohms while R_9 and R_6 are only 470,000 and 33,000 ohms, respectively.

From the grid of V_2, the positive sync pulse video signal is coupled through the integrating network R_9C_3 to the grid of V_3. With the tube biased beyond cutoff, only sync pulses cause conduction. R_9 and C_3 provide a time constant of approximately 25 microseconds. Therefore, the 5 microsecond horizontal sync pulses and the 2.5 microsecond equalizing pulses charge C_3 only slightly to produce very little positive voltage at the grid, and do not cause conduction of V_3; but the 27 microsecond vertical sync pulses are integrated to produce a large voltage pulse which drives this tube into conduction. The plate current pulse produces a voltage across R_8 and R_{10}, and this voltage is applied to C_5 and R_{11} in series. Due to this applied voltage, electrons flow from ground through R_{11} to the lower plate of C_5, and from the upper plate through V_3 and the B supply to ground. As C_5 has relatively large capacitance, .25 microfarad, the time constant of R_{11} and C_5 is long, about 1000 microseconds. Therefore, the charging current produces the vertical sync pulse voltage across R_{11}, but does not increase the voltage on C_5 to any great extent. Thus, V_3 continues to conduct during the entire vertical sync pulse group because its bias is not increased as is the case with V_2.

Resistor R_{11} forms a common cathode circuit load for V_2 and V_3. As explained, the 1st sync clipper produces horizontal sync and equalizing pulses across R_{11}, while, the 2nd sync clipper produces vertical sync pulses across this resistor. As a result, the composite sync pulse signal is combined or reassembled across R_{11}, from where it is applied to the cathode of tube V_4.

In the third sync clipper stage, R_{12} maintains the grid and cathode at about the same direct voltage, while C_6 maintains the grid at a-c ground potential. Since the signal input consists of positive going pulses applied to the cathode, it has the same effect as negative pulses applied to the grid. R_{13} and R_{14} form a voltage divider across the 300 volt B supply so that 60 volts is applied to the plate of V_4. With this low plate voltage, cutoff occurs at a relatively small grid-cathode difference of potential. Therefore, the positive sync signal pulses on the cathode drive V_4 into cutoff so that the tops of the pulses are clipped. This clipping action removes noise which may be superimposed on the tops of the sync pulses.



In this pentagrid sync separator system, a sync amplifier inverts the video detector output to provide the third grid of the separator tube with a signal 180° out of phase with that coupled directly from the detector to the first grid.

From the plate of V_4, positive sync pulses are coupled through C_7 to the grid of the phase splitter tube V_5. C_7 and R_{16} form a grid leak bias network which biases the grid negatively. The comparatively long duration vertical sync pulses charge C_7 more than the horizontal sync or equalizing pulses, and thus increase the bias. With a greater bias on the grid, V_5 provides sync pulses with reduced amplitude immediately after the vertical sync pulse. To overcome this condition, resistor R_{15} is connected from the grid to the +150 volt line, to apply a small positive voltage to the grid. This connection allows the charge on C_7 to leak off rapidly after the vertical sync pulse.

With positive pulses applied to its grid, the V_5 plate current is increased by each pulse to increase the voltage across each of the load resistors, R_{17}, R_{18} and R_{19}. This action produces negative pulses at the plate of the tube, and positive pulses at the upper ends of R_{18} and R_{19}. The negative plate pulses and the positive pulses across R_{19} are coupled through C_8 and C_9, respectively, to the horizontal frequency control circuit. The positive pulses at the V_5 cathode are applied to an integrating circuit (not shown), and to the vertical deflection circuit.

In the noise inverter circuit, the entire positive voltage across C_1 is applied to the cathode of V_1. The grid is connected to the junction between R_2 and R_3 so that it obtains a lower positive voltage than that applied to the V_2 grid. As a result of these applied voltages, the operating point of V_1 is so far negative beyond cutoff that no part of the composite video signal can cause conduction in this tube. That is, the tube is normally cut off. However, the video signal is applied to the grid from the junction between R_2 and R_3. When the signal contains noise pulses which exceed the amplitude of the sync pulses, these positive noise spikes make the grid sufficiently positive to overcome the bias and drive the tube into conduction. Since the noise pulses are positive at the grid of V_1, they produce negative pulses at the plate. The video signal applied from the junction of R_1 and R_2 to the grids of V_2 and V_3 has positive going sync and noise pulses. Therefore, these positive pulses in the video signal are cancelled by the negative noise pulses coupled from the V_1 plate through capacitor C_2 to the grid of V_2, and from here through resistor R_9 to the grid of V_3.

General Electric

The video and sync circuits employed in the General Electric Model 21T28, and other models, are shown in Figure 5. The sync section contains a pentagrid type separator and noise cancel circuit, followed by a direct coupled phase splitter amplifier. From two points in the video section, out-of-phase video signals are applied to the sync circuit input. One of these input signals is clipped by the limiting action of one grid in V_2 to produce a sync signal output free of picture and blanking information. Applied to another grid of V_2, the other signal cuts the tube off when noise pulses exceed the amplitude of the sync pulses.

The Figure includes the receiver video circuits to show the method of obtaining the out-of-phase video signals. In the detector circuit, the crystal diode D_1 is connected so that the i-f voltage alternations which make the upper end of L_1 negative produce diode current. Electrons flow from ground, up through L_1 and through D_1, L_2, L_3, and R_1 to ground. As a result, the ungrounded end of load resistor R_1

is made negative. Thus, at point X, the video signal has positive picture phase with negative going sync pulses. This signal is coupled through C_3 to the control grid of V_1 and also through C_6 to grid No. 1 of the sync separator tube V_2.

Inverted by the video amplifier, the video signal has negative picture phase with positive going sync pulses at the plate of V_1, and at point Y. From the junction between L_5 and R_6, the positive sync pulse video signal is applied through C_8, and parallel C_7 and R_7 to grid No. 3 of the pentagrid sync separator tube. This grid and the cathode act as a diode which rectifies the applied signal, charging C_8 as indicated. This charge partially leaks off through R_7 and R_{11} to the cathode, producing a voltage across R_{11} which biases the grid negative. This bias cuts off the tube, but because the charge is allowed to partially leak off, the sync pulses can overcome the bias and cause the tube to conduct.

The pulses of plate current cause the V_2 plate voltage to fall, thus producing negative sync pulses, stripped free of blanking and picture information, at point Z. Applied to the grid of the phase splitter tube V_3, these negative pulses are reproduced as positive going pulses at the V_3 plate, and negative going pulses at the cathode. From these points, they are applied to the respective deflection circuits as indicated.

The noise cancelling action of this type of sync separator has been explained in detail in a previous lesson. Reviewing briefly, a small positive voltage is applied to the first grid of V_2, causing this grid to lose control of plate current almost completely. Normally, the video signal applied from point X is too small to drive the V_2 first grid negative with respect to the cathode. But, when the signal contains a noise pulse which exceeds the amplitude of the sync pulses, this noise pulse drives the grid negative to cut off the tube. With the tube thus cut off, neither noise nor sync pulses appear in its output for the duration of the noise pulse. The temporary interruption of sync pulses is better than allowing noise to pass through to the deflection circuits.

Because of the power supply connections employed in this particular receiver, the cathode of V_2 is 130 volts positive with respect to ground. The purpose of this arrangement is explained in a later lesson, and has nothing to do with the action of the sync separator.

To make the first grid of V_2 a small amount positive with respect to the cathode, it is connected through R_8, R_9, and R_{10} to the

+275 volt B+ point, as indicated. With the grid positive, there is grid current. Electrons flow from the cathode to the grid, and through R_8, R_9 and R_{10} to B+. The cathode-to-grid resistance, R_{GK}, forms a voltage divider with R_8, R_9 and R_{10}. Each of these resistors has very large resistance compared with R_{GK} when the tube allows grid current. Therefore, most of the applied B+ voltage is across the three resistors, and only a small part is across R_{GK}. Because of this voltage divider action, the grid of V_2 is only slightly positive with respect to the cathode.

The positive voltage required on the 1st grid of V_2 depends upon the amplitude of the received signal. When the signal is strong, the grid must be operated sufficiently positive so that the negative going sync pulse cannot drive the tube into cutoff. If the sync pulse tips cut off the tube, the amplitude of the pulses produced in the output is reduced to cause partial loss of synchronism. However, the more positive the grid is operated, the less control it has, with the result that the explained noise cancelling action occurs only for relatively large amplitude noise pulses. Cancelling action on low as well as high amplitude noise pulses can be obtained when the received signal is weaker by operating the grid less positive, thus giving it more control.

The receiver of Figure 5 provides a means of selecting either of three different positive voltages for the first grid of V_2. With switch S_1 in the position shown, resistors, R_8, R_9, and R_{10} are in series between the V_2 grid No. 1 and B+. This position is for weak received signals, as it supplies the smallest positive voltage to the grid. Thus, in weak signal areas, where noise causes the most trouble, the noise canceller action is most effective. In the case of medium signal strength, S_1 is rotated so that R_{10} is shorted, and therefore a higher positive voltage is applied to the grid, lessening its control. Finally, when the received signals are strong, S_1 is rotated

SYNC CIRCUIT TUBES

SEPARATOR	AMPLIFIER
½ 6AN8	½ 12AU7
6CS6	½ 12AU7
6CS6	½ 6SN7GT
½ 5U8	½ 6SN7GT
½ 6SN7GT	½ 6SN7GT
½ 12AU7	½ 12AU7
6BY6	½ 6AN8
½ 6U8	6CG7
6BE6	6AV6
½ 5U8	½ 6SN7GT
3CS6	None
6C4	½ 6SN7GT

Typical combinations of tube types employed in the sync circuits of modern television receivers.

further to short both R_{10} and R_9. With only R_8 between the grid and B+, the largest positive voltage is applied to further reduce the grid control and, as mentioned, to prevent the sync pulses from cutting off the tube.

Sync Circuit Troubles

Just as in all other sections of the television receiver, every tube, capacitor, and resistor in the sync circuit is a necessary component, and is selected with regard to type or value to provide the desired circuit action. Therefore, any change in value or operation of a sync circuit component results in abnormal output, or loss of output, from the last sync stage, with consequent loss of synchronism in the reproduced picture. However, every case of loss of picture synchronism is not necessarily due to a defect in the sync circuits. For these circuits to perform their functions properly, they must receive the composite video signal of sufficient amplitude and without distortion. Thus, a fault in the r-f, i-f, or v-f circuits which results in a detected video signal that is too low in amplitude, or of improper waveform, can produce the loss-of-sync symptoms.

If the video signal amplitude is not great enough, the grid leak bias developed in the sync separator grid circuit may not operate the tube at a sufficiently negative operating point. As a result, the tube may pass part or all of the blanking and picture information along with the sync signals. Thus, the blanking and picture signals trigger the deflection circuits, causing them to lose synchronism.

As an example of a fault within the sync circuit, suppose plate load resistor R_7, of the sync separator of Figure 1, decreases in resistance. This defect causes two changes in the operation of V_1. First, with the lower resistance, plate current produces a smaller voltage across R_7, and the plate voltage of V_2 rises. With higher plate voltage, the I_b-E_c characteristic shifts so that the operating point is no longer sufficiently negative with respect to cutoff. As a result, the desired separating action cannot take place, and the picture and blanking signals appear in the plate circuit, along with the sync pulses.

Second, with the decreased plate load resistance, the gain of the stage is decreased also. Therefore, V_2 does not amplify the signals as intended. As indicated in the Figure, 25 volt PP sync pulses are required at the sync separator plate to properly drive the phase inverter stage. This fault will cause horizontal pulling of the picture, vertical rolling, or complete loss of synchronism, depending upon the extent of decrease in R_7 resistance. The same symptoms can be produced by a weak sync separator tube or sync amplifier tube.

Poor vertical synchronism, with normal horizontal synchronism, results due to leakage in any of the integrator circuit capacitors, C_6 or C_7 in Figure 1, or C_4, C_5, or C_6 in Figure 2.

If there is leakage in coupling capacitor C_2, Figure 2, this capacitor may not maintain a charge sufficient to produce the high grid leak bias required by the sync separator tube. Then, V_2 does not separate the sync pulses from the composite video signal, with resultant loss of both horizontal and vertical synchronism.

A defect such as leakage in capacitor C_1, Figure 3, reduces the bias on the noise cancel tube V_3. The video signal applied to the cathode then causes this tube to conduct for sync pulses, and possibly blanking and picture signals as well, instead of only high amplitude noise pulses. As the video signal then produced at the V_3 plate is 180° out of phase with that coming from the plate of V_2, these two signals partially cancel so that a very weak video signal is applied to the sync separator stage. Sufficient grid leak bias is not produced, proper separation cannot occur, with consequent loss of synchronism.

As explained for the circuit of Figure 5, the phase splitter amplifier has its load resistance in two sections, R_{15} in the cathode circuit, and R_{16} in the plate circuit. If R_{15}, for example, were to decrease in resistance, there would result a reduction in amplitude of the sync pulses applied to the horizontal control circuit. This defect would cause poor horizontal synchronization, with normal vertical sync.

The above possible troubles in sync circuits merely describe what could happen if such defects occur. Naturally, there are many others. The object of later lessons is to explain how to isolate and correct faults in various sections of a receiver.

Except for the added components employed to extend the pass band, the video amplifier of a television receiver is similar to the voltage amplifier stages employed in the audio section of a radio. Both video and audio signals consist of complex mixtures of alternating voltages and, neglecting their respective frequency ranges, are much the same. However, the video signals also must include information concerning the average or background illumination of the transmitted scene so that the various elements or details are reproduced on the receiver screen with the original respective degrees of brightness or shading.

D-C RESTORATION

Screen Brightness Levels

On the receiver screen, the brightness of the scanning line pattern, or raster, is determined by the bias of the picture tube control grid. The more negative the grid with respect to the cathode, the fewer the electrons which reach the screen, and the lower the brightness level. If the grid bias is decreased, more electrons reach the screen and a higher level of brightness is obtained.

The background brightness of the picture tube screen is determined by the bias applied between its grid and cathode.

Courtesy Radio Corporation of America

Called a brightness or brilliance control, a potentiometer is included in the picture tube cathode or control grid circuit to provide a means of adjusting the grid bias, and thus determine the operating point of the tube. The signal voltage is applied to the grid and causes its instantaneous voltage to vary about the operating point.

Although these signal variations produce picture elements which are respectively darker and brighter than the average level of screen brightness, they do not give any information regarding the average brightness of the scene scanned at the studio. Therefore, if this potentiometer were the only brightness control in the receiver, the viewer could adjust it for some desired level of average brightness, but he would not know whether a generally dark or bright scene was being viewed by the television camera.

Reference Level

To provide a basis for the proper adjustment of the brightness controls of the receivers tuned to any particular station, the transmitted signal contains a brightness reference level. This reference could be the zero signal level which produces maximum white on the screen, or a level corresponding to some definite shade of gray, between maximum white and black.

Since the various degrees of screen brilliance vary with different picture tubes and receiver circuits, the only practical reference is the signal level which causes zero brightness or a "black" screen. Known as the black level, this is the reference used in modern television systems.

Nature of the Television Signal

For any particular picture tube, the cutoff grid voltage is always the same. Therefore, the grid bias must be controlled in such a way that the blanking pulses are able to reduce the scanning spot intensity to zero, regardless of the average brightness of the picture being received.

To provide this condition, the blanking pulses have greater amplitude than the black level, and the viewer may use them as a refence. To cause the picture details to have their correct respective brightness levels, with respect to black, it is simply necessary that the blanking pulses reduce the screen brightness to zero.

As explained, the black level is transmitted at a fixed signal amplitude, while the modulation corresponding to the details of the scene causes the signal level to vary from instant to instant in accordance with the relative intensities of the picture elements scanned by the camera. For proper reproduction of a television scene, not only the picture details, but also the background must have the proper brightness with respect to black. The background brightness level may be thought of as a zero axis with the instantaneous intensities of the picture details varying above and below.

This zero axis, or background brightness level, may remain constant for a comparatively long period of time, or it may change slowly, or more rapidly. However, even the relatively rapid changes are quite slow compared to the video frequencies corresponding to the details of the scene. Whether constant or changing, the background brightness seldom decreases to zero or black level.

Hence, there is a d-c difference of potential between the zero axis and the black level of the picture signal. If the background of the reproduced image is to have the proper level with respect to black, the transmitted signal must retain this **d-c component.** Furthermore, the receiver should operate in such a way that the d-c component controls the grid bias of the picture tube. For this reason, many television receivers contain an "automatic brightness control" circuit which, together with the brightness control potentiometer, determines the actual negative bias on the picture tube grid. The automatic brightness control circuit must be responsive to changes in the d-c component so that any variations of the background illumination are reproduced.

D-C Insertion at the Transmitter

In the process of forming the complete video signal at the transmitter, the picture signal a-c axis may be adjusted to its proper value with respect to the blanking level by the addition of a direct voltage, the magnitude of which is determined by the average brightness of the scene. This direct voltage usually is inserted in the grid circuit of one of the tubes in the transmitter mixing circuit, and its amplitude adjusted by an engineer seated in the control booth where he can observe the scene being televised.

For example, when a generally dark scene is being scanned in the studio, a low direct voltage is inserted so that the signal a-c axis is not far below the level of the blanking pulses, as indicated by E_{d-c} in Figure 6E. When a bright scene is being scanned, a higher direct voltage is inserted, and the a-c axis falls well below the blanking level, as indicated by E_{d-c} in Figure 6F.

Modulated by the video signals of Figures 6E and 6F, the television r-f carrier can be represented by the curves of Figures 6A and 6B, respectively. Regardless of the nature of the transmitted scene, the carrier increases to 75% of its peak amplitude for the blanking pulses and to 100% for the sync pulses. However, the average amplitude, above or below the zero axis, is greater in the case of the dark picture of Figure 6E than it is for the bright scene of Figure 6F.

Loss of the D-C Component in the Receiver

In the mixer stage of the receiver, modulated carriers like those of Figures 6A and 6B are heterodyned with the output of a local oscillator and the modulation is transferred to a lower or intermediate frequency. The action is the same as that of a superheterodyne radio receiver and the modulated i-f is increased in magnitude as it passes through the i-f amplifier. Except for its lower frequency and greater amplitude, the output of the i-f amplifier is a replica of the incoming signal with an envelope like those of Figures 6A or 6B.

Acting as the video detector, a diode with the signal of Figure 6A applied to it has an output of the form shown in Figure 6C. With an input signal like Figure 6B, the output is like Figure 6D. However, in practice, the detector load resistor is shunted by the capacitances of the tube and circuit which filters the intermediate frequency so that the actual usable output has a form which more closely resembles those shown in Figures 6E and 6F. Thus, the detector demodulates the i-f carrier, and its output wave-form is a replica of the original video signals produced at the transmitter.

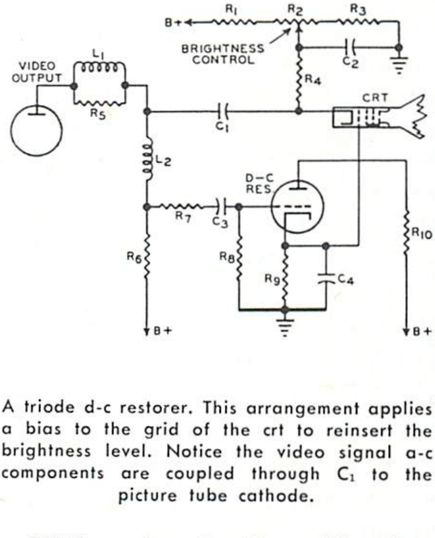
The video amplifier increases the magnitude of the detector output voltage, without causing any change of frequencies therefore, the curves of Figures 6E and 6F can represent the video signal voltage impressed across the control grid circuit of the picture tube.

A resistance-capacitance coupling circuit is show in Figure 7A where e_{v-f} represents the applied signal voltage, e_g represents the portion of e_{v-f} which appears across R_1, C_1 is the coupling capacitor and R_1 is the grid resistor. The cathode of the CRT connects to the slider on potentiometer P_1 which is part of a voltage divider between the "+" of the plate voltage supply and ground.

The grid bias is controlled by the position of the sliding contact of P_1, and the portion in series with the cathode is bypassed by capacitor C_2. By regulating the bias supply voltage E_{cc}, potentiometer P_1 serves as the manually operated brilliance or brightness control.

In television, the polarity of the signal voltage is important because the blanking pulses must drive the picture tube grid negative to produce a "black" screen. These pulses are indicated as positive in the curves of Figures 6E and 6F. With this polarity, they can be applied to the cathode of the picture tube, or they can be inverted and impressed on the grid with negative polarity as indicated in the curves of Figure 7B.

In the normal action of an amplifier stage, the input grid voltage is 180° out of phase with the output plate voltage. Therefore, with a detector output as shown in Figure 6, an odd number of video amplifier stages provide the inverted output voltage of Figure 7B.



A triode d-c restorer. This arrangement applies a bias to the grid of the crt to reinsert the brightness level. Notice the video signal a-c components are coupled through C_1 to the picture tube cathode.

With a signal voltage like that of Figure 6E inverted and applied across the e_{v-f} terminals of Figure 7A, the coupling capacitor C_1 blocks the d-c component and only the variations or a-c component appear across grid resistor R_1. This a-c component e_g is indicated by the dark picture curve of Figure 7B, and the average level is indicated by the reference line or axis located so that the curve forms equal areas above and below it. To emphasize the action in the curves of Figure 7B, the sync and blanking pulses have been enlarged and the actual picture signals reduced.

With a signal like that of Figure 6F inverted and applied across the e_{v-f} terminals of Figure 7A, the resulting voltage e_g is indicated by the bright picture curve of Figure 7B. Although both curves of Figure 7B are drawn on the same average level or base line, the pulses of the dark picture are less negative than those of the bright picture, while the other parts of the bright picture are more positive than those of the dark picture. Thus, the d-c blocking action of the coupling capacitor has changed the fixed reference for the signal from the blanking level to the average signal level.

To illustrate the transfer of these changes of grid voltage to corresponding variations of screen brightness, the I_bE_c characteristic curve of the picture tube of Figure 7 is shown in Figure 8. The e_g voltages of Figure 7B are added to the d-c bias E_{cc} and, for this explanation, assume that control P_1 has been set so that the negative blanking pulses of the bright picture drives the grid negative to cutoff.

To illustrate this action, the direct voltage applied to the grid is indicated by the broken vertical line in Figure 8. The a-c grid voltage is shown by superimposing the e_g curves of Figure 7B on this line. Then, projecting these values upward to the characteristic curve, the resulting instantaneous changes of screen brightness are plotted to the right. These brightness curves indicate the reproduction of the bright picture would be satisfactory as the image details are between gray and white while the blanking pulses drive the grid negative to cutoff and cause a black screen.

However, for the dark picture, the image details are too bright and the blanking pulses are not sufficiently negative to cause a black screen. By increasing the negative bias until the dark picture pulses drive the grid to cutoff, correct reproduction could be obtained, but then the bright pictures would be too dark. Thus, to reproduce pictures with proper average brightness and blanking pulses sufficiently negative to reach the black level, it would be necessary to adjust the bias voltage for each change of scene.

D-C RESTORER CIRCUITS

While this is possible, it is not practical as almost constant adjustment would be necessary. Therefore, circuits have been developed to make the required changes automatically. Since in effect, the automatic change of bias restores the d-c component of the original signal, the circuit is known as a d-c restorer. The common types of d-c restorers are described in the remainder of this lesson.

Diode D-C Restorer

One d-c restorer employs the coupling circuit of Figure 7A with the addition of a diode as shown in Figure 9A. For simplicity, all frequency compensating and decoupling units are omitted and only the basic coupling units between the video amplifier tube V_1 and picture tube V_3 are indicated. The diode tube V_2 is connected directly across, in parallel with, grid resistor R_1.

The parallel combination of R_1 and V_2 is in series with coupling capacitor C_1 between the plate of V_1 and ground and also in series with the d-c bias voltage E_{cc} in the V_3 grid-cathode circuit. The coupling capacitor C_1 blocks the d-c plate voltage of tube V_1, but as the incoming signals cause variations of plate voltage, the resulting charge and discharge currents of C_1 are carried by the R_1V_2 combination.

When the receiver power is turned on, the plate voltage of tube V_1 is impressed across capacitor C_1 which charges through grid resistor R_1. During this action, electrons flow from ground through resistor R_1 to one capacitor plate which becomes negative, thereby forcing electrons from the other plate, through V_1, plate load resistor R_L to B+ and through the plate supply to ground. This flow of electrons through R_1 causes a voltage which is positive toward the grid of V_3 as indicated.

With capacitor C_1 charged and no change of tube V_1 control grid voltage, there is no electron flow through, or voltage across, R_1. Therefore, the negative plate of C_1, the grid end of R_1, the cathode of diode V_2, and the control grid of picture tube V_3 are at ground potential. However, the cathode of tube V_3 is maintained positive with respect to ground, by the voltage across the lower portion of potentiometer P_1. With the cathode as the reference point, the control grid of V_3 is E_{cc} volts negative.

With signal voltages like those of Figures 6E and 6F impressed on the control grid of tube V_1, Figure 9, the plate voltage varies according to the curves of Figure 7B and these changes are impressed on coupling capacitor C_1. However, the v-f amplifier plate is never negative with respect to ground. Therefore, the curves of Figure 7B represent the variations of positive voltage. By considering the horizontal line as the normal or "no-signal" plate voltage, the "+" parts of the curve represent increases while the "−" parts represent decreases of plate voltage.

Connected between the plate of V_1 and ground, capacitor C_1 charges as the plate voltage increases and discharges as the voltage decreases. During the capacitor charge, the electron flow follows the path explained previously, and the resulting voltage across R_1 has the indicated polarity. While the capacitor discharges, the electron flow is from the negative plate through R_1 to ground and through the tube V_1 from cathode to plate, to the capacitor positive plate. During intervals of capacitor discharge, the polarity of the voltage across R_1 is reversed so that its grounded end is positive. Thus, variations in the positive voltage on the plate of tube V_1 cause an alternating voltage across resistor R_1.

Connected with its plate to ground, diode V_2 is in parallel with resistor R_1. Therefore, any voltage across the resistor is impressed across V_2 also. While capacitor C_1 is charging, the polarity of the voltage across R_1 drives the cathode of V_2 positive with respect to the plate, therefore the tube is non-conductive. However, with capacitor C_1 discharging, the polarity across R_1 reverses, the cathode of V_2 is negative with respect to the plate, and the tube becomes conductive. Because of this action, C_1 charges through the comparatively high resistance of R_1 and discharges through the low resistance of R_1 and V_2 in parallel.

C_1 and R_1 are so chosen that the RC time constant of the charging circuit is equal to the interval of about 10 horizontal lines. Therefore, for each individual line of the image, the charging current is fairly constant. Carried by resistor R_1, the charging current causes a voltage which is impressed on the grid-cathode circuit of the picture tube.

In the circuit of Figure 9A, there are two sources of voltage. First, the voltage E_{cc} across the lower portion of potentiometer P_1. This voltage maintains the grid negative with respect to the cathode. Second, the voltage across resistor R_1. Proportional to the charging current of capacitor C_1, this voltage has a polarity that tends to drive the grid positive with respect to the cathode. Thus, the net grid bias is equal to the difference between these two opposing voltages.

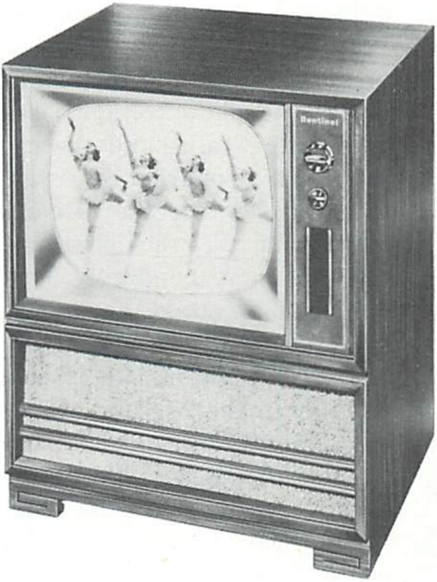
#9

When capacitor C_1 discharges, tube V_2 becomes conductive and the resulting low resistance of the parallel combination reduces the voltage across R_1 to a negligible value. Under these conditions E_{cc} is the only effective voltage in the grid-cathode circuit.

Potentiometer P_1 is adjusted so that, with no signal input, the picture tube grid is biased to beam cutoff, or zero screen brightness. Also, with the receiver in operating condition, with no signal input, coupling capacitor C_1 is charged to the plate voltage of tube V_1 and there is no voltage across R_1.

To illustrate the action with signal voltages like those of Figure 7B, the plan of Figure 8 has been used for Figure 9B. Again, the signal voltages on the grid are shown at the lower left, and the bias voltage E_{CC} is adjusted to slightly beyond cutoff. As the first negative blanking pulse causes a sudden drop in the plate voltage of V_1, capacitor C_1 discharges rapidly to the lower value. As diode V_2 is conductive during this action, the discharge has no appreciable effect on the grid voltage of V_3.

At the expiration of the blanking pulse, the plate voltage of V_1 rises suddenly to its former value and capacitor C_1 starts to charge immediately. As diode V_2 is nonconductive during this action, the charging current is carried by resistor R_1 and the resulting voltage across it drives the grid of V_3 more positive or less negative. The voltage across R_1 is proportional to the difference between the average plate voltage of V_1 and the lower value caused by the blanking pulse. The magnitude of this difference is shown by arrow E_{R_1} in the bright picture curves of Figure 9B.



For a bright scene such as this, the picture tube grid operates only slightly negative with respect to the cathode voltage.

Courtesy Sentinel Radio Corp.

Since E_{CC} is greater than E_{R_1}, the net bias is equal to $E_{CC}-E_{R_1}$ and in this case, is indicated by the position of the vertical dashed line that intersects the I_b-E_c curve near its middle. Intersecting the curve at the same point, a horizontal dashed line indicates the relatively high average beam current, and therefore, high average screen brightness, due to the bright picture signal.

For a dark picture, the general action is exactly the same, but the difference between the average signal level and the negative blanking pulses is much less than for the bright picture. Therefore, the blanking pulses cause a smaller reduction of V_1 plate voltage and capacitor C_1 discharges less. After the expiration of the blanking pulse the plate voltage rises to its average value and the capacitor starts to charge. However, as this voltage increase is comparatively small, the charging current is correspondingly low. The resulting voltage across R_1 is indicated by arrow E_{R_1} at the lower left of Figure 9B. Since E_{R_1}, is small, the net bias, $E_{CC}-E_{R_1}$, is large so that the operating point is near the low end of the I_b-E_c curve. As a result, the average brightness of the scene is reduced to its proper value.

This arrangement automatically varies the picture tube screen brightness to correspond to the difference between the dark level and average level of the transmitted signal. Thus, in effect, it restores the d-c component indicated as $E_{d\text{-}c}$ in Figures 6E and 6F.

In the upper right section of Figure 8, the screen brightness varies above and below the average level of the signals and the blanking pulses of the dark picture do not reach the black level. In the upper right section of Figure 9B, all blanking pulses extend to the black level, which is the reference, and the average level is at the proper distance above the reference.

To simplify the explanations of Figure 9, it was assumed that each blanking pulse caused diode V_2 to become conductive. In actual operation, a state of equilibrium is reached after which only the extremely negative sync pulses overcome the voltage across E_{R_1} and cause conduction of V_2. The diode current during these pulses is indicated by curve I_d of Figure 9B. Due to these short current pulses, the voltage across R_1 varies with scenes of different average brightness to provide the action as explained.

To prevent interaction with the signal coupling circuits, in practice, the diode d-c restorer is isolated, as shown in Figure 10. Here, the signal coupling capacitor C_3 is connected from the junction between peaking coils L_1 and L_2 in the plate circuit of the video amplifier output tube V_1 to the control grid of picture tube V_3.

Compared with the circuit of Figure 9A, R_2 and L_2 replace R_L; R_5, R_6, and R_7 replace R_1, and C_5 replaces C_2. So far as the video signals are concerned, the coupling action is the same in both circuits. The d-c restoration is obtained by means of resistor R_4, capacitor C_4, and diode V_2 connected across resistor R_6. The action of these components is as explained for C_1, R_1, and V_2 of Figure 9A.

Resistor R_4 limits the current in the circuit of C_4 when diode V_2 is conductive. As the restorer circuit is connected to the junction between L_2 and R_2, its capacitances are isolated from the plate-cathode circuit of the video output tube V_1. In much the same way, resistor R_5 provides a conductive path for the grid of picture tube V_3 but isolates the capacitance of the diode.

Grid Leak D-C Restorer

A second type of d-c restorer circuit is shown in Figure 11A. The output of video amplifier V_1 is direct coupled to the grid of picture tube V_2. C_1 and R_1 provide grid leak bias for V_1 while R_L serves as the plate load resistor for V_1 and as the grid resistor for V_2. Potentiometer P_1 is the manual brightness control.

Reviewing briefly, the grid leak bias is produced as a result of cathode-to-grid electron flow in V_1. The positive peaks of input signal e_I drive the amplifier grid positive with respect to the grounded cathode and, captured by the grid, electrons travel to C_1 which thus becomes charged to the peak value of e_I and to the polarity indicated. During the interval between positive signal peaks, C_1 discharges slightly through R_1, the electrons leaving the negative plate of the capacitor and flowing down through R_1 to ground so that the voltage E_{R_1} has the polarity indicated.

The capacitance of C_1 and the resistance of R_1 are relatively large, therefore C_1 does not discharge to a very great extent between positive signal peaks but is recharged fully by each peak. Because of this, the discharge current of C_1 maintains the grid bias, E_{R_1}, at a value only slightly less than the peak applied signal voltage, and only the positive sync pulses are able to overcome this bias and cause cathode-to-grid conduction of V_1.

The bias E_{R_1} is directly proportional to the peak amplitude of the applied signal, and therefore, it is greater for a bright-picture signal having high amplitude blanking pulses than for a dark-picture signal having low amplitude blanking pulses. In other words, tube V_1 operates with a variable grid bias which is determined by the amplitude of the blanking pulses of the video signal.

The I_b-E_c characteristic of V_1 is represented by the curve of Figure 11B. The wave-forms in the lower left show that a bright-picture signal develops a large bias E_{R_1}, causing the tube to operate at a low point on the curve.

In contrast, a dark-picture signal develops a small bias, E'_{R_1}, causing the tube to operate at a high point on the curve.

In the upper right of the Figure, the horizontal dashed lines represent the average plate current for the respective picture conditions. As shown, the difference in these values results in the tops of the blanking pulses being at the same level. That is, the d-c component has been restored by the action of the V_1 grid leak bias circuit.

To retain the reinserted d-c component, it is necessary to employ direct coupling between the output of the video amplifier and the picture tube. Therefore, no blocking capacitor is used between the plate of V_1 and the grid of V_2 in Figure 11A.

As explained for Figures 9 and 10, the d-c component of the video signal is employed to automatically vary the bias of the picture tube so that the average brightness level of the screen corresponds to that of the transmitted scene. In the circuit of Figure 11A, the picture tube grid-cathode d-c circuit includes R_L and the portion of potentiometer P_1 between B+ and the slider. Since it is connected through R_L to B+, the picture tube grid would be positive with respect to the cathode by an amount equal to E_{CC} if there were no voltage across R_L. However, V_1 plate current develops a voltage, E_{R_L}, having the polarity indicated, so that the V_2 grid-cathode circuit contains the two series-opposing direct voltages, E_{R_L} and E_{cc}. Determined by the setting of brightness control P_1, E_{cc} has a fixed value, while the average of E_{R_L} varies directly with that of the V_1 plate current, as indicated at the extreme right of Figure 11B.

Figure 11C shows the I_b-E_c characteristic curve of the picture tube of Figure 11A. With the cathode potential as a reference, voltage E_{cc} is shown as a positive value. However, the series opposing negative voltage E_{R_L} is greater than E_{cc}, so that the net grid bias E_c is negative. For a bright-picture signal, the average value of E_{R_L} is low, and the difference between it and E_{cc} is small, causing the tube to operate at a relatively high point on the curve. For a dark-picture signal, the heavier average video amplifier plate current produces the higher voltage, E'_{R_L}, and the large difference between this and E_{cc} provides a high net negative bias E_C so tube V_2 operates nearer cutoff as indicated.

Figure 11C shows that the screen brightness level is high in the case of the bright-picture signal and low when the dark-picture signal is being received, while all blanking pulses reduce the brightness to the black level. These, of course, are the desired picture tube operating conditions and correspond to those shown in Figure 9B.

In the circuit of Figure 11A, failure of the input signal will result in V_1 operating at zero bias, and thus permit a heavy plate current. A high E_{R_L} is produced to bias the V_2 grid to cutoff. In like manner, in the circuit of Figure 9A, failure of the signal results in loss of the positive direct voltage E_{R_1}, allowing the negative bias to cut off the picture tube beam. Thus, both of these circuits automatically reduce the spot intensity to the black level. Therefore, the fluorescent coating of the picture tube screen is not damaged by excessive electron bombardment when, for any reason, there is no signal input to the video amplifier.

The grid leak type d-c restorer is used in the video amplifier circuit of Figure 12. Operated with its cathode at ground potential, video amplifier V_1 has its bias developed across grid resistor R_1. A d-c blocking capacitor is not employed in the output coupling circuit, the V_1 plate being connected directly through coil L_1 to the grid of picture tube V_2. The cathode of V_2 obtains its positive voltage from the slider on potentiometer P_1, while the grid is connected through L_2 and R_5 to the +190 volt terminal of the power supply. Thus, the grid voltage is equal to 190 volts minus the voltage, E_{R_5}, produced by the V_1 plate current.

Average scenes, such as this, have backgrounds which are about midway between white and black. If the brightness and contrast controls are set for proper reception of this type of scene, generally the lack of d-c reinsertion is not noticeable.

Courtesy Emerson Radio and Phonograph Corp.

The slider on P_1 is set so that the cathode is more positive than the grid, thus providing the proper grid-cathode operating voltages for the picture tube. The action of this circuit is like that explained for the simplified circuit of Figure 11A. Briefly, in Figure 12, the V_1 grid leak bias is proportional to the amplitude of the blanking pulses of the applied video signal. Thus, the high amplitude pulses of a bright-picture signal result in low plate current and voltage, E_{R_5}, permitting V_2 to operate with small negative bias and high average beam current, while the low amplitude pulses of a dark-picture signal result in a high E_{R_5} so that V_2 operates with reduced average beam current.

DIRECT COUPLING

As mentioned earlier, the d-c component is lost when the signal passes through the v-f amplifier because of the d-c blocking capacitors used in the interstage coupling circuits. This loss of the d-c component is prevented, and the need for a d-c restorer eliminated, by the employment of direct-coupled v-f amplifiers. #10

This arrangement is used in the circuit of Figure 13 which includes the video detector, the 1st v-f amplifier, the v-f output stage, and the picture tube grid-cathode circuits of a commercial television receiver. Detector V_1 is coupled directly through L_2 to the grid of first v-f amplifier V_2, the plate of which is coupled directly through L_4 and L_5 to the grid of V_3. The plate of the v-f output tube is coupled directly through R_{13} to the grid of picture tube V_4. Thus, with direct coupling from the output of the detector to the grid of the picture tube, the signal d-c component is retained at all times.

When direct-coupled amplifier stages are employed, the grid of each tube obtains its operating voltage from the same source as the plate of the preceding tube. At the same time, the proper direct voltage relations must be provided for the various elements of each tube. This circuit requires a voltage divider system like that shown along the lower portion of Figure 13. Extending from the −125 v to the +120 v terminals of the power supply, this divider consists of potentiometer P_1 and resistors R_{15}, R_{16}, R_{17}, and R_{18}. Operating at the same voltage, the plate of V_1 and grid of V_2 are supplied −125 volts through R_3, R_2, L_3, and L_2.

To permit proper operation of V_1, its cathode circuit is connected to the junction between R_2 and R_3, this junction being held at signal ground potential by C_2. The V_2 cathode is connected through R_4 to the slider on potentiometer P_1, which is connected from the −125 v terminal to the −80 v terminal. Hence, the cathode is less negative, or more positive, than the grid. In a like manner, the V_2 plate is connected through L_4, L_5, R_6, and L_6 to the −50 volt terminal and, therefore, it is less negative (or more positive) than either the cathode or the grid. Connected to the + 25 v terminal, the screen grid is operated at higher potential than the plate.

Disregarding the very small voltage across coils L_4 and L_5, the

V_3 control grid is at the same operating voltage as the V_2 plate. With respect to the −50 v power supply terminal, both the V_2 plate and V_3 grid are negative by the amount of the voltage across R_6. Connected from the −50 v to the −125 v terminals, is the voltage divider R_9, R_8, R_7, and L_7. The V_3 cathode connects to the junction between R_7 and R_8, and the various resistances are proportioned so that the cathode is positive with respect to the grid.

The V_3 screen grid is connected directly to the +120 v terminal, while the voltage divider consisting of R_{12} and L_8, R_{11}, R_{10}, R_{13}, and R_{21} in series is connected between this point and the −125 v terminal. As one end of this divider is positive with respect to ground, while the other end is negative with respect to ground, a point of zero potential must exist somewhere along the divider. In this receiver, R_{13} and R_{21} are each greater than 2 megohms, while the resistance total of the remaining sections of the divider is less than 10,000 ohms. Therefore, the point of zero potential actually lies somewhere along R_{13}. Connected to the junction between R_{10} and R_{13}, the V_3 plate therefore is positive with respect to ground.

The V_4 grid is connected to the junction between R_{13} and R_{21}, which is a few volts negative with respect to ground, while the cathode is connected to the slider on potentiometer P_2 which forms a part of a voltage divider connected from the +120 v to the −50 v power supply terminals. In the coupling circuit between V_3 and V_4, the signal d-c component is coupled through R_{13}, while the a-c components are coupled through C_8, C_9, L_9, and R_{14}.

IMAGE EFFECTS VARY WITH SCENES

As explained, in receivers which employ a coupling capacitor between the video amplifier and picture tube, either a bright scene is reproduced too dark, or a dark scene is reproduced too bright, depending upon the setting of the brightness control, if there is no d-c restorer. However, since only a few scenes are very bright or very dark, an optimum setting of the brightness control can be found such that the absence of d-c restoration is scarcely noticeable for most of the scenes.

In the case of a bright scene, the overall darker image produced on the screen of a receiver without a d-c restorer or direct coupling is not noticed either, since the viewer has no way of knowing how bright the scene is at the studio. Thus, it is only the dark scenes which, in some but not all cases very definitely require d-c restoration for proper reproduction.

For example, suppose brightness control P_1 in Figure 9A is set to provide operation as indicated for the bright picture signal in Figure 9B, in a receiver which does not have a d-c restorer.

As coupling capacitor C_1 connects through R_1 to ground, this capacitor is charged to a voltage equal to the average of the plate of V_1, with respect to ground. The V_1 plate voltage variations cause C_1 to alternately charge and discharge through R_1, thus producing across this resistor a signal voltage which is applied to the grid of V_3. This signal voltage varies the V_3 grid positive and negative with respect to the bias E_{cc}.

Due to the bright picture signal, the average plate voltage of V_1 is relatively high. Therefore, the average voltage across C_1 is high also. Suppose now, the picture signal changes to the form produced by a dark scene at the studio. For the dark picture signal, the average V_1 plate potential falls to a lower positive value. To reduce to this lower average voltage, the coupling capacitor discharges, with electrons flowing from the negative plate of C_1, down through R_1 to ground, through V_1 to the opposite capacitor plate. This discharge current produces a direct voltage component E_{R_1}, which aids the bias E_{cc}. In this case, the polarity of E_{R_1} is opposite that indicated in the Figure.

With the negative voltage E_{R_1} added to E_{cc}, the total bias on V_3 is relatively high, and the picture tube grid operates near cutoff as indicated for the dark picture signal. However, as C_1 continues to discharge, its discharge current gradually decreases and the negative voltage E_{R_1} decreases. If the scene contains one or more vertical "white columns", or lines, this information is represented by large amplitude positive swings of the signal during a portion of each scanning line. These highly positive excursions of the signal recharge C_1 to some extent to replenish the energy lost due to its discharge during the dark parts of the scene. With its charge replaced by the white columns in the scene, C_1 can provide a reasonably large discharge current during the remainder of each scanning line, and thus maintain the negative voltage E_{R_1}. So long as E_{R_1} is provided in this manner, the total bias on the picture tube grid is large, and the grid operating point is near the lower end of the I_b-E_c curve, as it should be for proper reproduction of a mostly dark scene.

Because of the action just described, a mostly dark scene containing white columns results in reasonably good reproduction in a receiver using capacitive coupling, even though a d-c restorer is not employed. Due to this fact, and because the lack of d-c restoration is not noticeable for most other types of scenes, many manufacturers do not include a d-c restorer in their television receivers.

To continue with the above example, suppose the dark scene does not contain white columns, but instead, has only one or two relatively small white objects. That is, the white objects have short vertical dimensions so that they cover only a few scanning lines. An example is a lighted candle in a darkened room. In the reproduced image, the room should be nearly black, except for the area near the candle.

In this case, after the picture signal changes from the bright to the dark form, Figure 9B, the coupling capacitor begins to discharge as before, to produce the negative voltage E_{R_1}. At the beginning of the discharge action, the discharge current and therefore E_{R_1} are large. This value of E_{R_1} added to E_{cc} produces a high total bias to operate the picture tube near cutoff, as shown for the dark picture signal in Figure 9B. During the portions of the scene where there is no bright object, there are no positive swings of the signal to recharge capacitor C_1. Therefore, C_1 continues to discharge with an ever decreasing discharge current. The negative voltage E_{R_1} decreases at a rate determined by the time constant R_1C_1.

Although the background is dark in this image, the vertical white central portion supplies energy during each scanning line to maintain the large bias needed by the picture tube grid for proper operation, even though the receiver may not contain a d-c restorer.

Courtesy Bendix Radio Division of Bendix Aviation Corp.

As E_{R_1} decreases, the total negative bias on the grid of V_3 becomes less, so that the operating point gradually shifts toward positive, or to the right in Figure 9B. Finally, when C_1 has discharged to the lower average voltage of the V_1 plate there is no more discharge current, and the direct voltage component E_{R_1} becomes zero. With E_{R_1} equal to zero, the only bias on the picture tube grid is E_{cc}. The dark picture signal then varies about the operating point determined by E_{cc}, as shown in Figure 8B. Thus, instead of being black, or nearly black, the "dark" portion of the reproduced scene is only dark gray, or even light gray, depending upon the setting of the brightness control.

The small white objects permit C_1 to recharge to some extent, so that proper operation is obtained during the scanning lines containing the objects, and a few lines thereafter. But, as the discharge current of C_1 dies down, the screen again becomes gray. Thus, with a dark scene of this type, improper shading of the background is produced in the picture in these receivers which employ capacitive coupling without a d-c restorer.

Usually, it is necessary to make correcting adjustments in signal level and shading at the transmitting station when the program switches from a studio scene to film pick up, or vice versa. If these adjustments aren't made at the station, the motion picture scenes may appear too dark at the receiver, or the studio scenes too bright, due to the faithful reproduction by a receiver containing a d-c restorer. As a result, the viewer must make compensating adjustments of contrast and brightness each time such a program switch occurs.

Although it is due to the fact that the transmission levels are not correct for the various scenes, this need for frequent adjustment of brightness and contrast is interpreted as a receiver fault by many viewers. Some servicemen have found it possible to satisfy this complaint by removing the d-c restorer. As explained, without a restorer, the dark scenes are lighter and the bright scenes darker than the originals. Thus, all scenes approach a medium brightness level. The owner then has a receiver which does not give as faithful reproduction as it did before, but he does not have to make adjustments as often.

On the other hand, some owners of receivers which do not have a d-c restorer complain of the uneven shading effects produced during the dark scenes, as described above. If the contrast and brightness controls are working properly, this complaint indicates that the viewer notices the lack of d-c restoration. In these cases, customer satisfaction is gained by installing a d-c restorer. In fact, some servicemen add a d-c restorer to receivers which come into their shop and which do not already contain such a circuit.

IMPORTANT DEFINITIONS

D-C COMPONENT—in television, the video signal level which corresponds to the background brightness of the televised scene.

D-C RESTORER—in a television receiver, a circuit in which diode action provides automatic regulation of the crt bias in such a may that the d-c component of the video signal is reinserted.

STUDENT NOTES

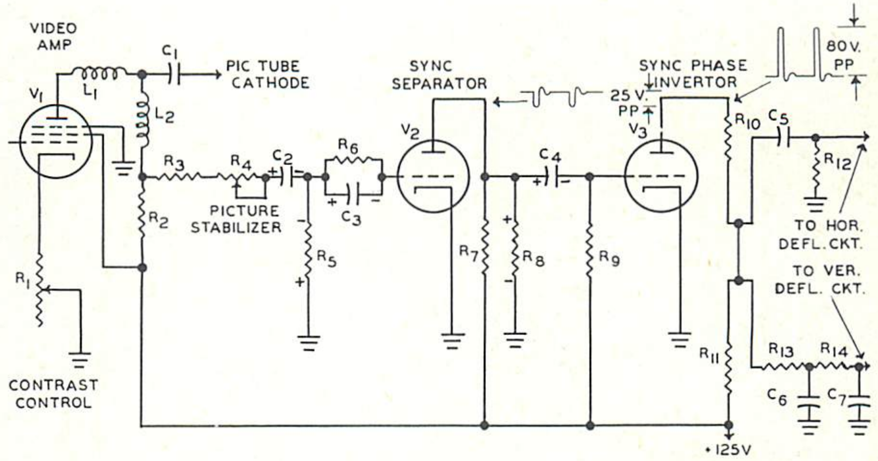


FIGURE 1

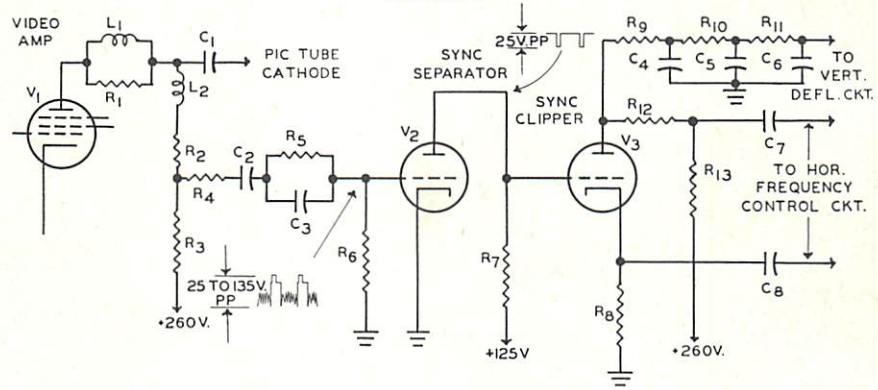


FIGURE 2

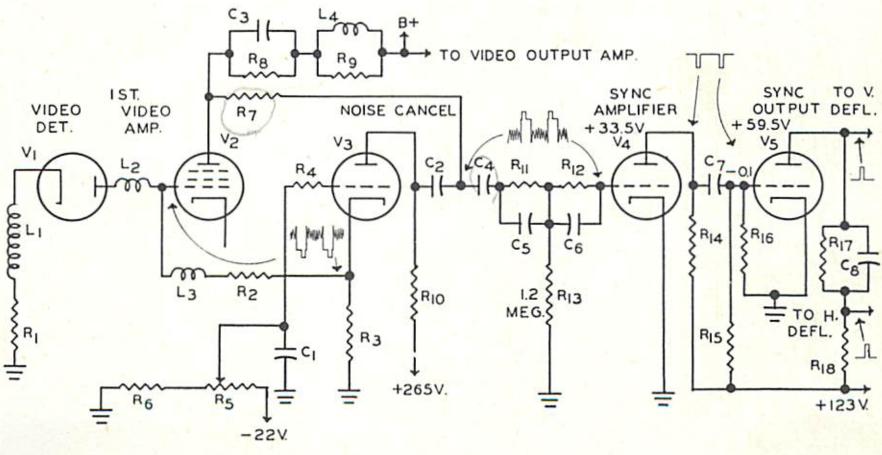
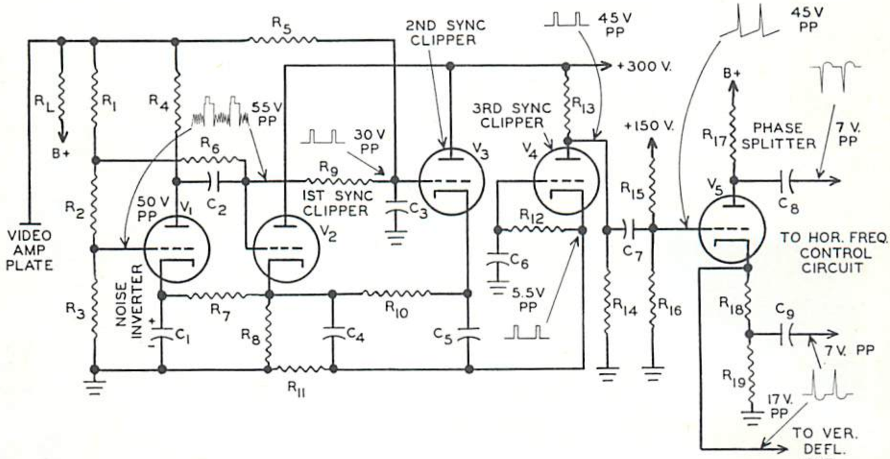


FIGURE 3



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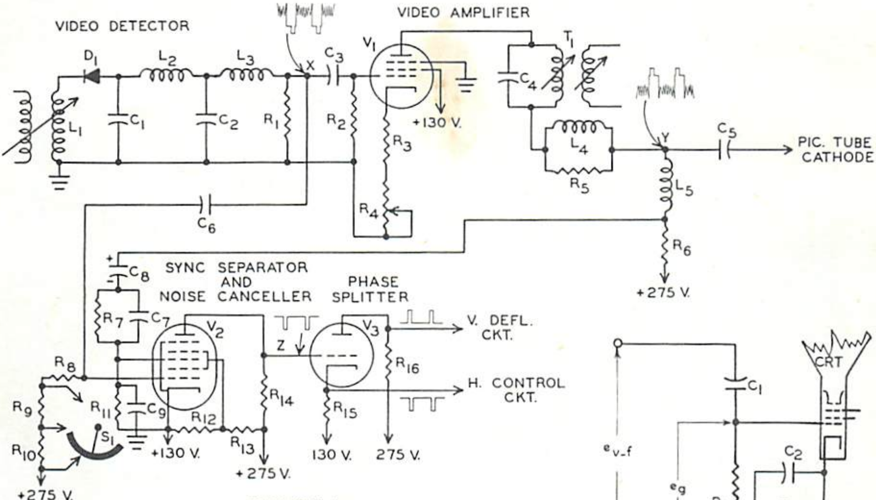

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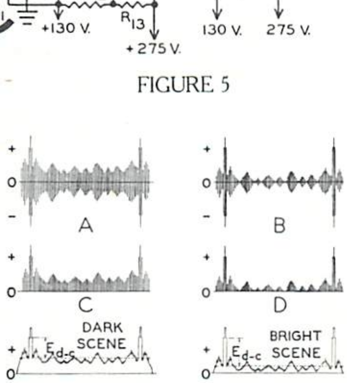


FIGURE 6

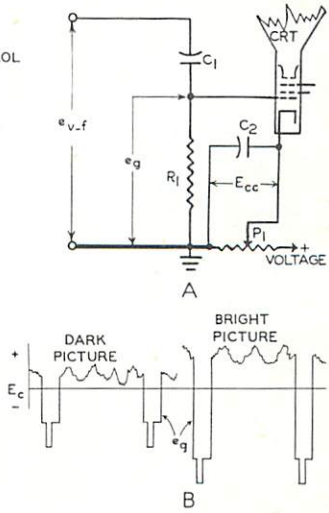


FIGURE 7

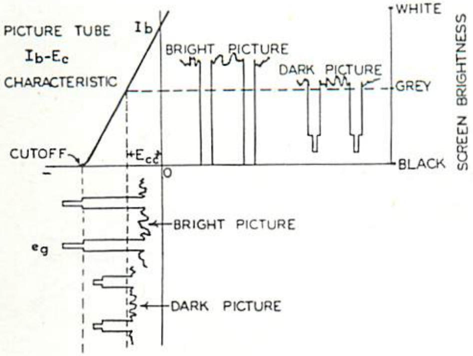
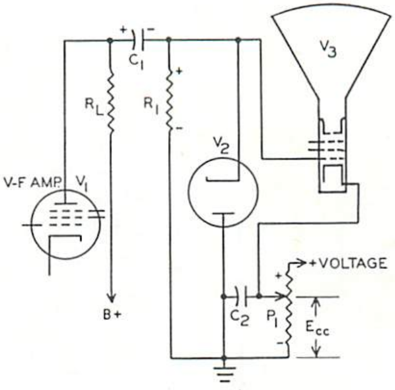


FIGURE 8



A

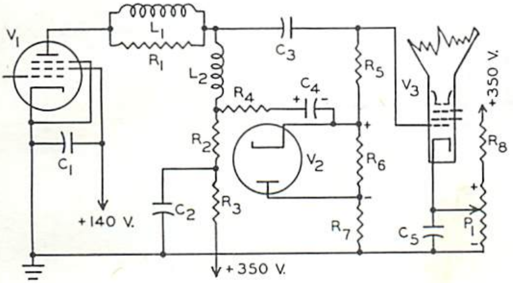
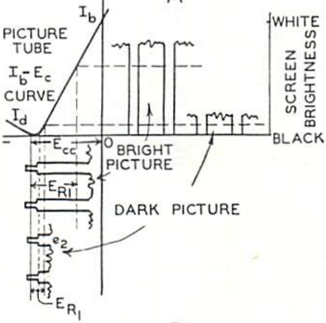


FIGURE 10



B

FIGURE 9

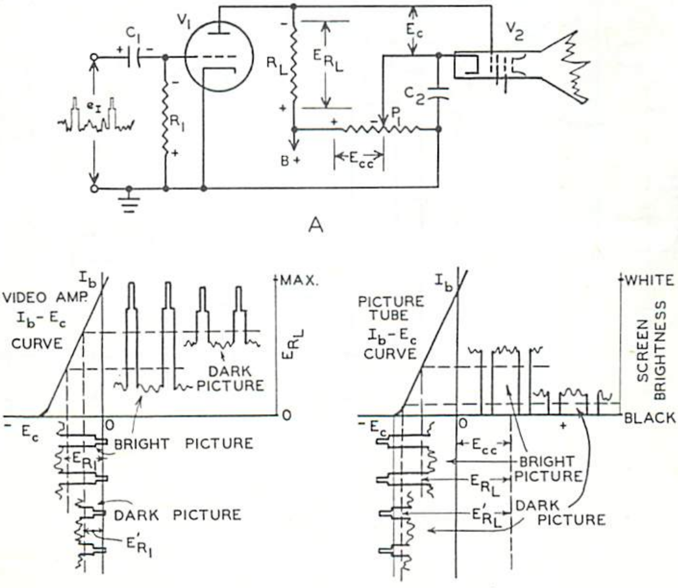


FIGURE 11

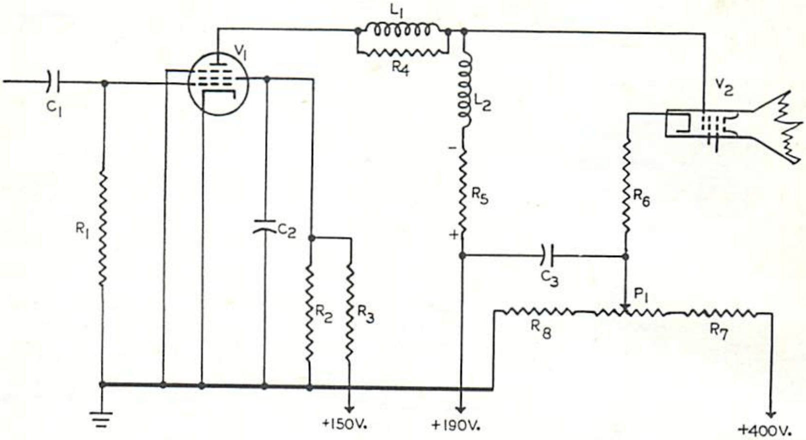


FIGURE 12

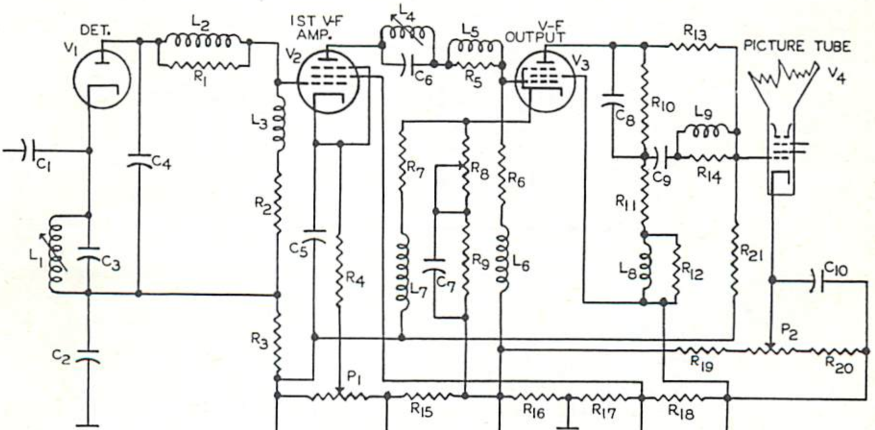


FIGURE 13

FROM OUR *Director's* NOTEBOOK

THERE ARE NO SHORT CUTS

The sooner a man is convinced that there are no short cuts in life, the better for him. Some men, however, never seem to realize it. To the end of their lives they have a notion that there exists a short cut to success, a short cut to reputation, a short cut to happiness—if they could only find it.

They walk along the high road with a continual sense of grievance. Every now and then they deviate to the right or to the left, hoping to be able to cut a corner; but we always find them returning to the main road, and invariably a little way behind the spot at which they left it.

Yours for success,

W. C. De Vry

DIRECTOR

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